Air Force Research Laboratory

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ADAPT

CCMC
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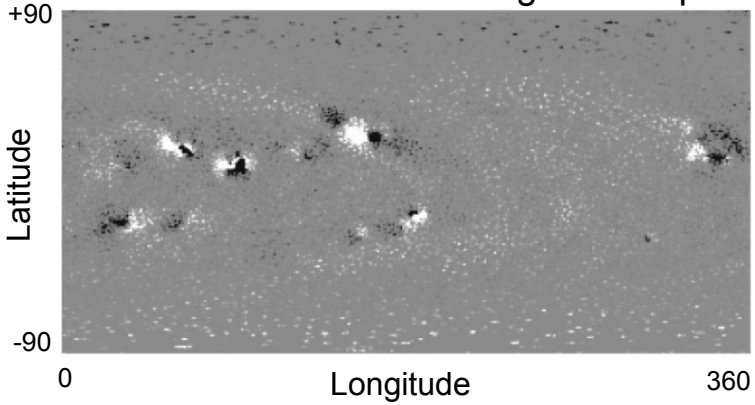
AFRL

Overview

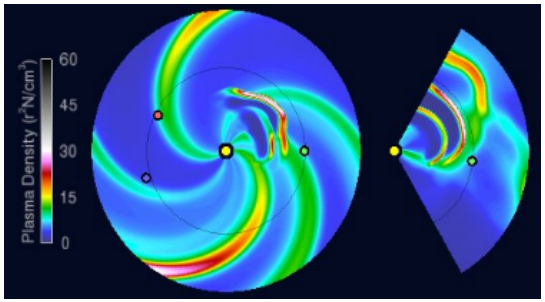
- The **ADAPT** (Air Force Data Assimilative Photospheric Flux Transport) model generates global solar magnetic maps

ADAPT Global Solar Magnetic Map



Original Goal

Solar Wind Modeling

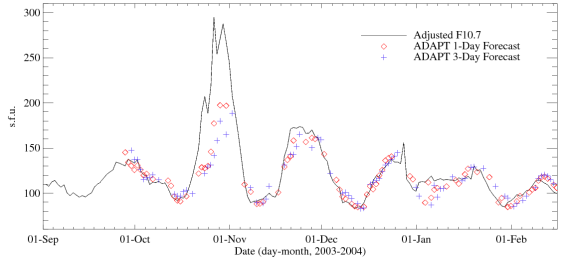


Credit: WSA-Enlil

ADAPT driven 4-day Solar Wind Forecast

Byproduct

Irradiance Modeling



ADAPT 3-day F10.7 Forecast

- ADAPT project started ~10 years ago:
  - Maps originally developed to drive solar wind forecasts
  - Now, maps also drive solar F10.7 and EUV forecasts
    - Irradiance modeling w/ **SIFT** (Solar Indices Forecasting Tool)
    - SIFT project started ~7 years ago

ADAPT Model:
development history & status

Start: 2007 *via* Air Force Office of Scientific Research (AFOSR) funding

Original Goal: combine NSO's Worden & Harvey magnetic flux transport with Los Alamos National Laboratory Kalman Filter (KF) data assimilation code:

- **flux transport code -** in IDL, originally designed for daily input only
- **data assimilation code -** in fortran90, no spatial constraints on KF

Coordination: ~1.5 active programmers at any given time

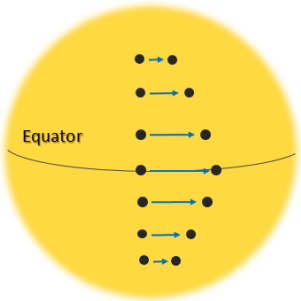
Now: the core of ADAPT is written in C, with the following libraries:

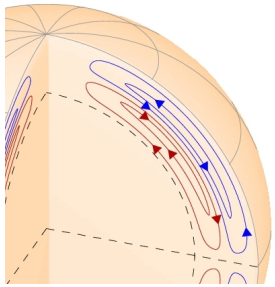
- **CFITSIO** (input/output in FITS, Flexible Image Transport System)
- **GFortran** [*may remove in 2018*]
- **GSL / GSL-Devel** (GNU Scientific Library)
- **MySQL** [*may remove in 2018*]
- **Open MPI**
- **Python 3**:
  - AstroPy, Matplotlib, NumPy, PyEphem, PyMySQL, SciPy, SunPy
- **XML**

ADAPT Model:
flux transport & data assimilation

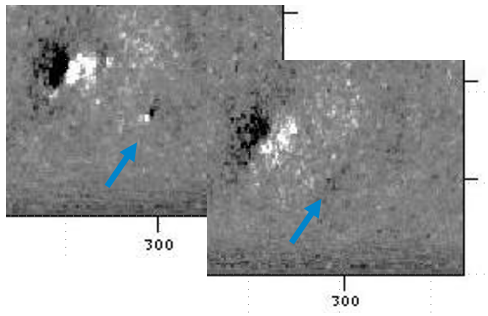
- **ADAPT Magnetic Flux Transport:**
  accounts for known surface flows across the surface of the sun:
  - **Differential rotation**
  - **Meridional poleward flows**
  - **Supergranulation diffusion**

  to align old data with observations



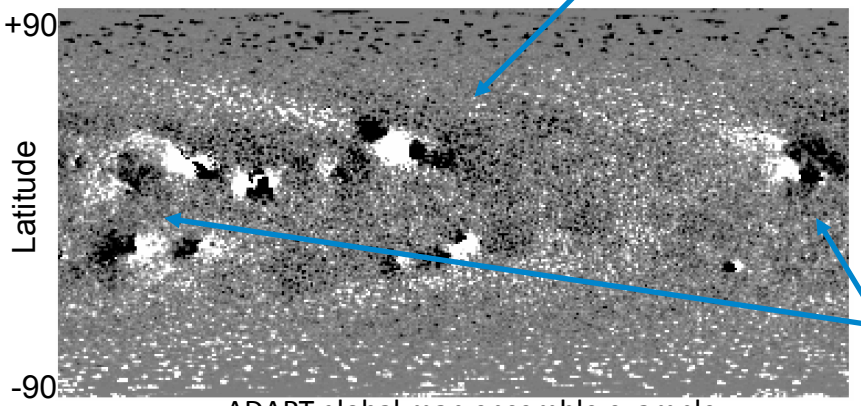


Credit: Zhao et al. 2014



- **ADAPT Data Assimilation:**
  assimilates observations using the ensemble least-squares estimation method, utilizing the variances of the model forecast ensemble and observed data.

Movie of 12 ADAPT model realizations representing the transport uncertainty for given instant in time



ADAPT global map ensemble example

For more information regarding ADAPT data assimilation see:
Hickmann, Godinez, Henney, Arge 2015, Solar Physics, 209, 1105

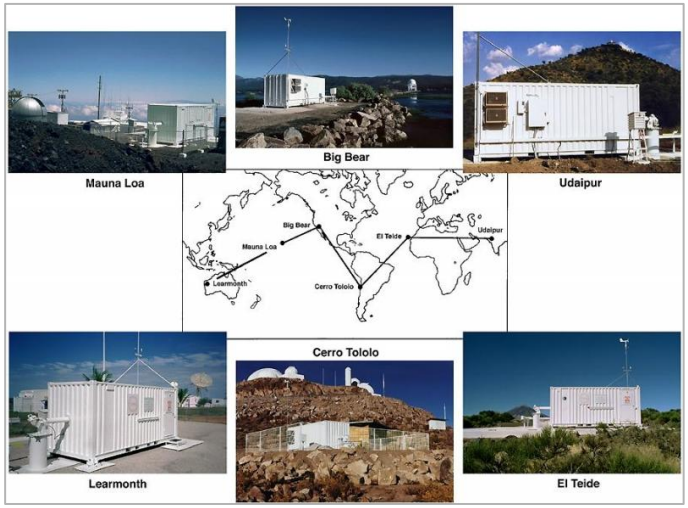
ADAPT Model Input:
magnetogram sources

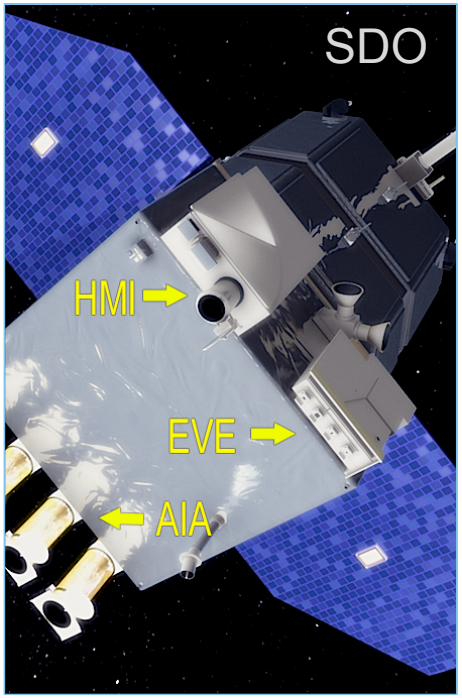
KPVT: 1992 (soon 1977) – 2003
[24 hr, single site, 868.8 nm]
NISP/VSM: 2003 – present
[24 hr, single site, 630.2 nm]
NISP/GONG: 2006 – present
[10 min, 6 sites, 676.8 nm]
SDO/HMI: 2010 – present
[12 min, Sat-GEO, 617.3 nm]

Kitt **P**eak **V**acuum **T**elescope

NSO **I**ntegrated **S**ynoptic **P**rogram:
Vector **S**pectro**M**agnetograph

NSO **I**ntegrated **S**ynoptic **P**rogram:
Global **O**scillation **N**etwork **G**roup



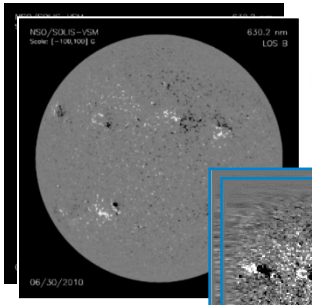


Helioseismic and **M**agnetic
Imager (on the **S**olar
Dynamics **O**bservatory)

ADAPT Model:
Modeling Framework

Provided by each Observatory (SDO/HMI, NSO GONG & VSM)

L1 observation in "sky frame" at obs_time

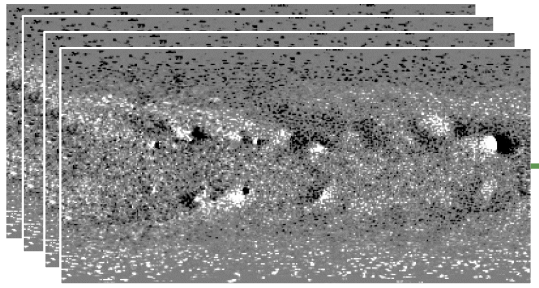


30 June 2010
NSO SOLIS/VSM

Magnetogram *data* & *uncertainty* remapped into heliographic coordinates: longitude vs. latitude (180 x 180 deg).

New preprocessing aligns all B_r input data (far & near) within model frame (i.e., 360x180; Carrington)

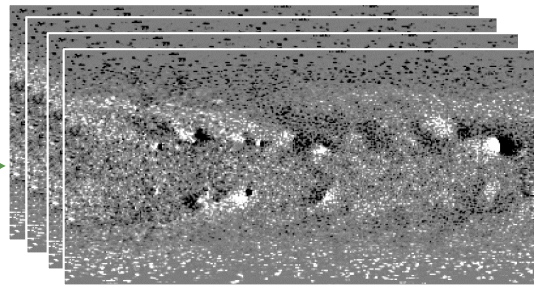
Model ensemble from *previous time step*



Forward Modeling
Differential Rotation
Meridional Circulation
Supergranulation

Data Assimilation *using EnLS Method*

Model ensemble *at obs_time*



Future input: *Solar Orbiter-PHI, plus L1 & L5/L4 magnetographs*

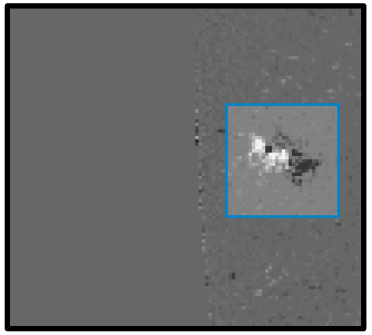
Reverse Active Region Modeling:
far-side "forensics"

Reconstruction of AR evolution:

1) Start with given AR on the east-limb
2) Estimate emergence from STERESO
3) Use mean evolution profile to reverse AR

1

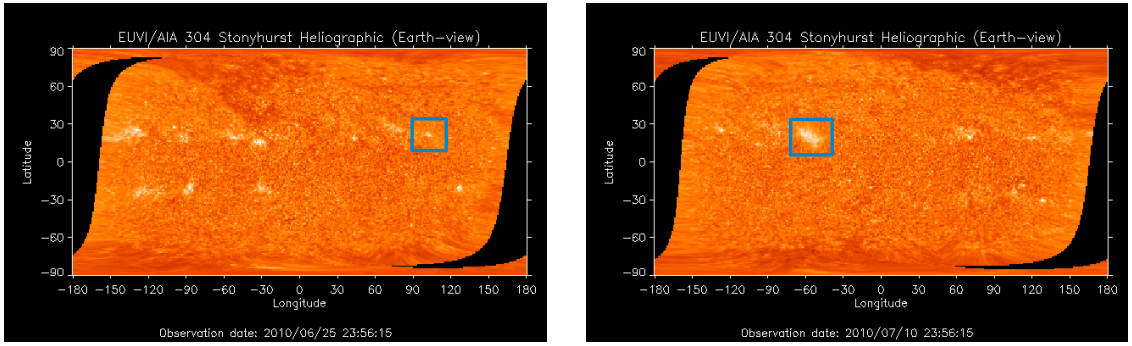
HMI Vector
10 July 2010 @ 1059 UT



AR11087

2

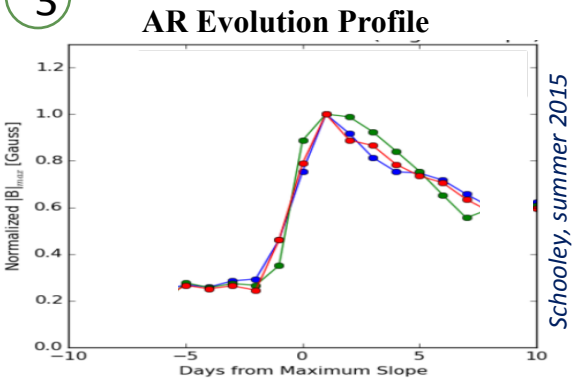
STEREO* EUVI (30.4 nm)



25 June 2010 ← 10 July 2010

Obs Time

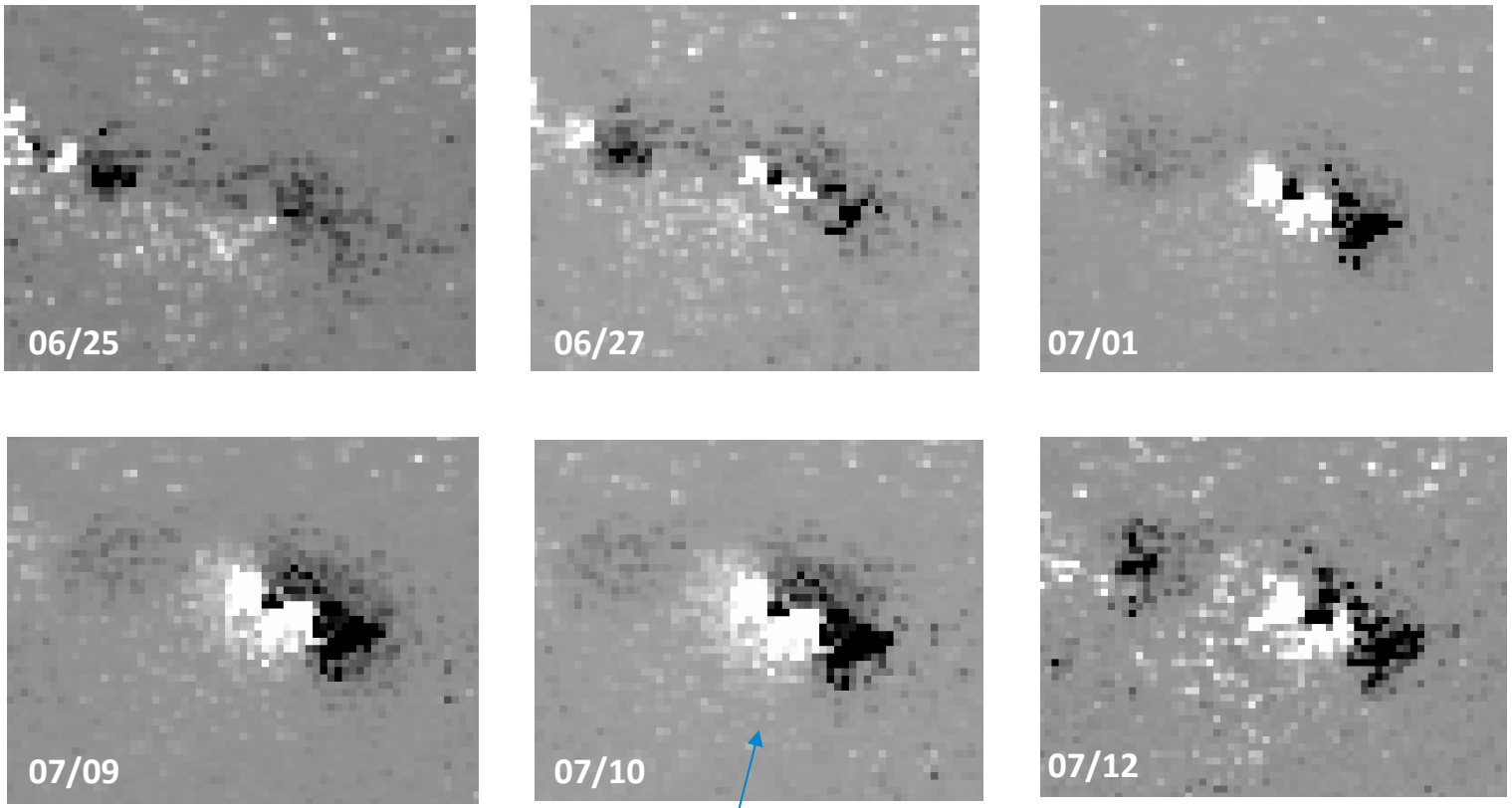
3



* Note: *only STEREO-A data is available after Oct 1, 2014, however, STEREO-B may become available at a later date.*

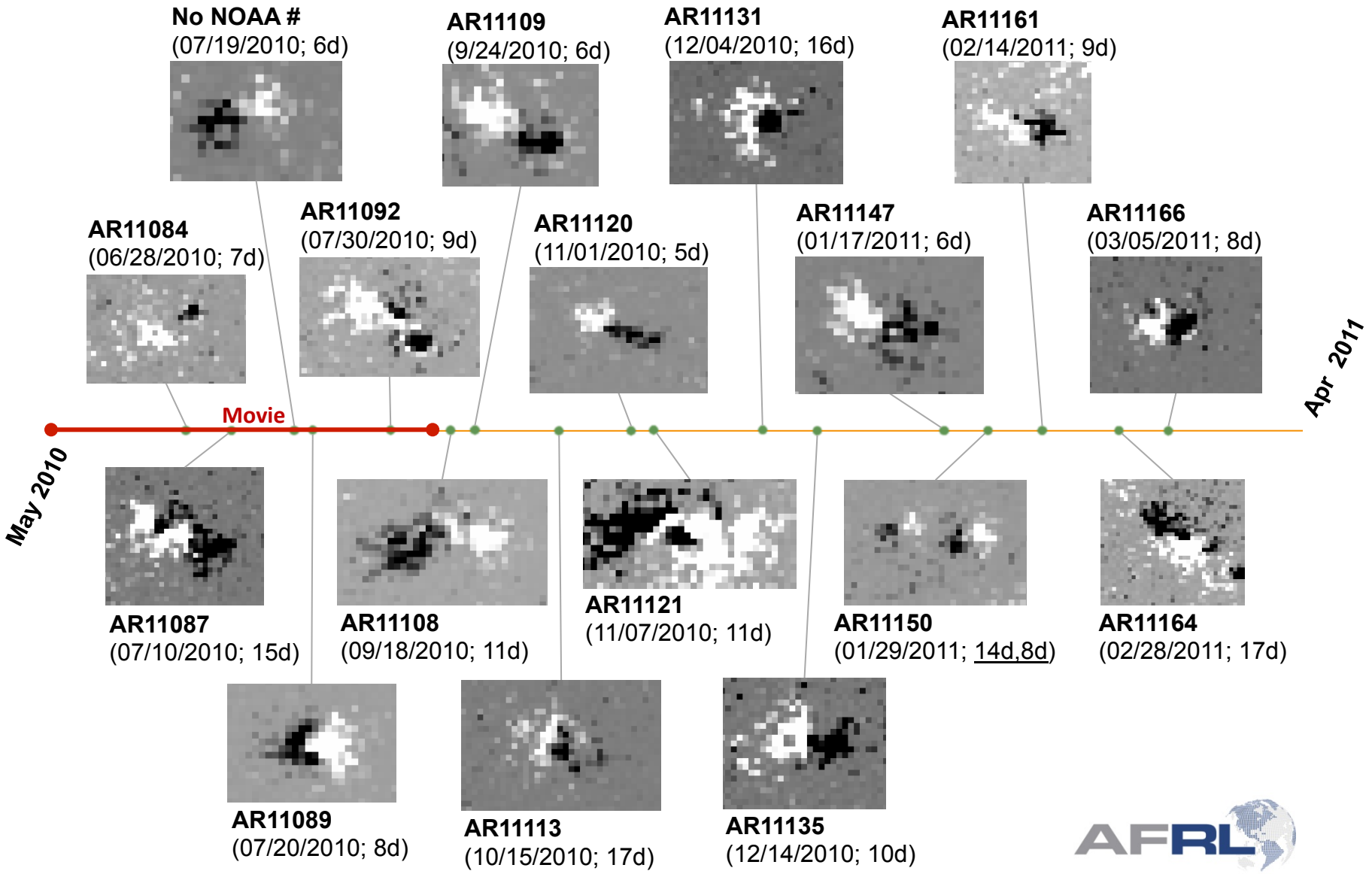
Reverse AR Evolution Example:
AR11087

ADAPT with AR11087 (seed data from 10 July 2010; emergence ~6/25):



Reverse Active Region "Yearbook":

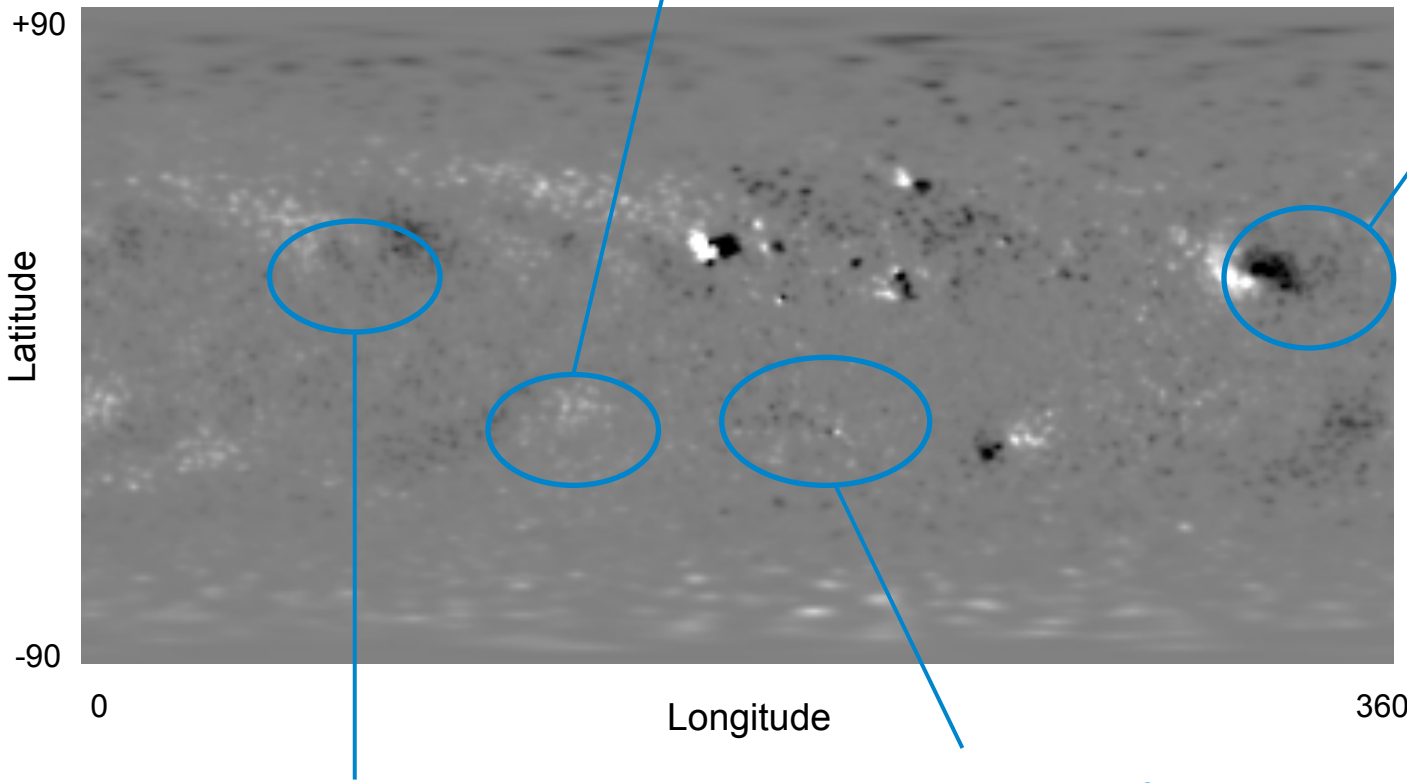
May 1, 2010 to March 5, 2011



ADAPT HMI Vector with RARs:
the movie (May 1, 2010 to Sep 15, 2010)

4. modeled far-side AR flux, AR11108, emerges on 9/7

ADAPT global map movie (realization 1 @ 24 hour cadence)



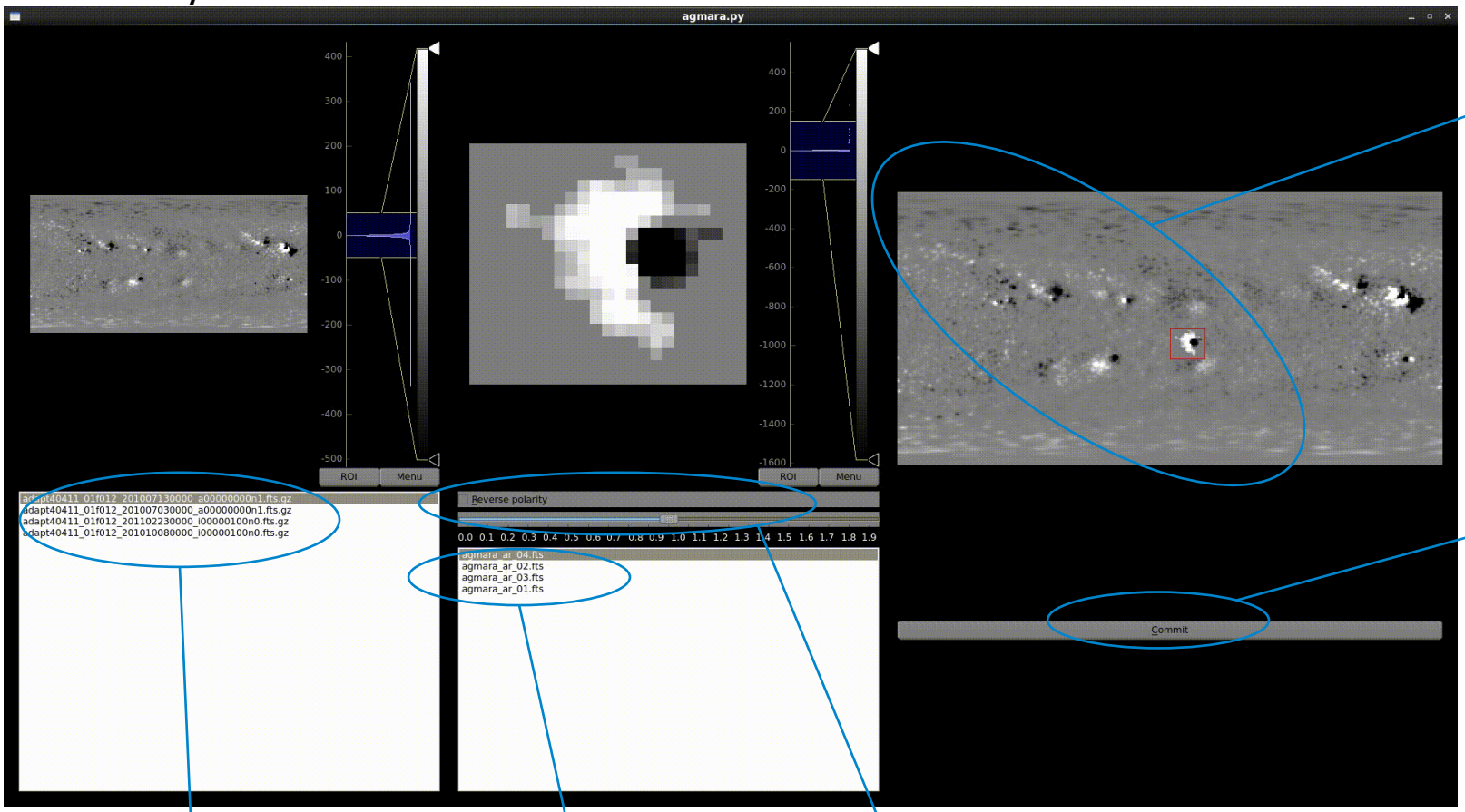
1. Starts with returning flux, then near-side AR before modeled far-side AR11087 emerges 6/25

3. modeled far-side AR flux, AR11092, emerges on 7/21

2. Modeled far-side AR11089 emerges on 7/12/2010

AGMARA Tool:
user driven AR modeling

Preliminary screenshot of the AGMARA* Tool:



Select AR position

Save new ensemble

Select ADAPT map

Select AR

Scale AR and/or flip polarity

*AGMARA - *ADAPT Global Map Active Region Assimilator*

Summary:
ADAPT maps online

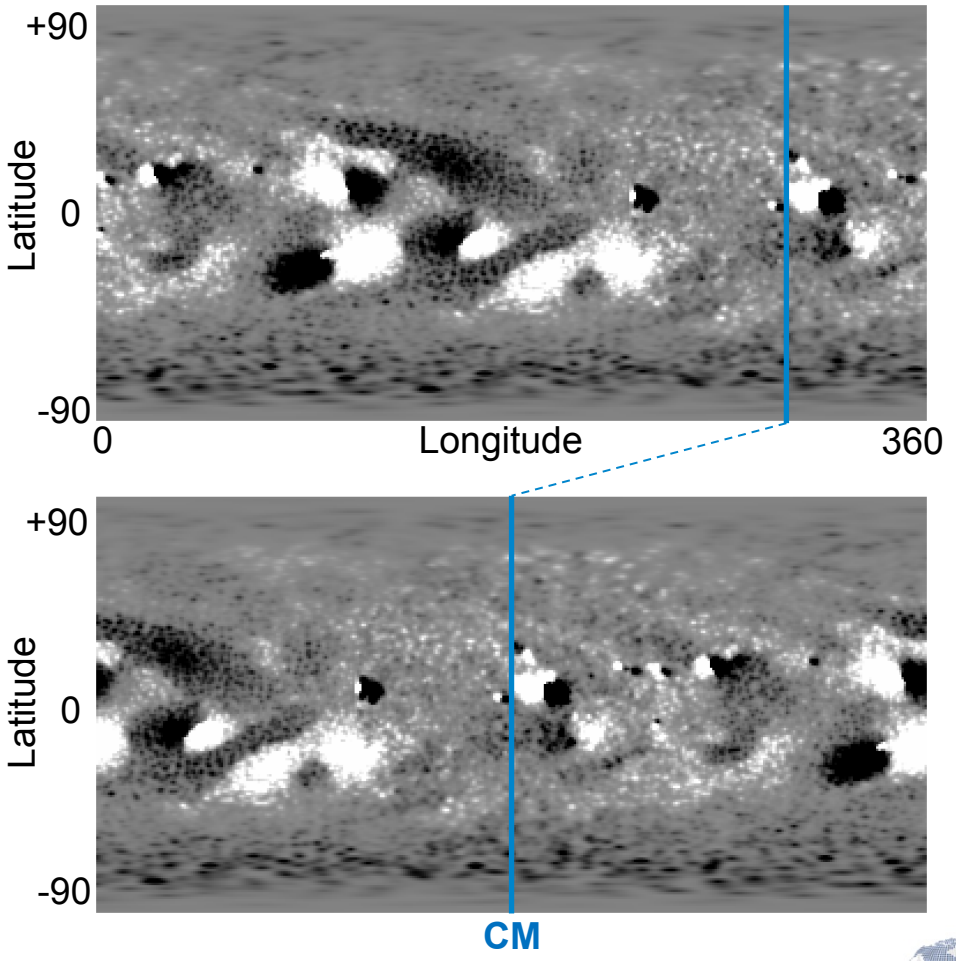
Two types of ADAPT/GONG maps are generated daily at the National Solar Observatory (NSO) at: **ftp://gong2.nso.edu/adapt/maps/gong/**

Carrington Frame

Sub-directory: YYYY/.
Prefix: "adapt403"
Cadence: 2 hours
Realizations: 12*

Central Meridian Frame

Sub-directory: YYYY/.
Prefix: "adapt413"
Cadence: 2 hours
Realizations: 12*

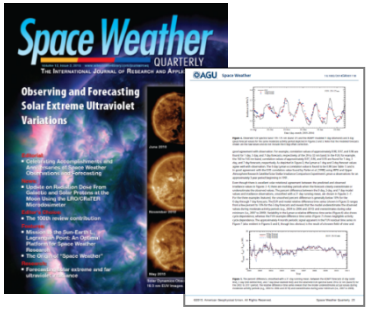


Example ADAPT maps for 05nov2015 @ 12 UT

* *Currently, realizations only differ by supergranulation flow pattern.*

Links & References

- Near real-time ADAPT maps at: ftp://gong2.nso.edu/adapt/maps
- And, $F_{10.7}$, Mg II, and SSN forecasts at: ftp://gong2.nso.edu/adapt/sift
- Related References:



Forecasting Solar Extreme and Far Ultraviolet Irradiance

Henney, Hock, Schooley, Toussaint, White, Arge 2015,
Space Weather, 13, 141-153
& ***Space Weather Quarterly, 12, 19-31***

Data Assimilation in the ADAPT Photospheric Flux Transport Model

Hickmann, Godinez, Henney, Arge 2015,
Solar Physics, 209, 1105-1118

Acknowledgements

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